TECHNICAL BULLETIN No. 161 DECEMBER, 1929

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

IMP. BUR.
18 FEB 1930
ENTOM.
XVII-479

LIFE HISTORY, HABITS, AND CONTROL OF THE MORMON CRICKET[1]

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INTRODUCTION

The work reported in this bulletin was begun in Hot Springs County, Wyo., in 1923 by F. W. Boyd.[3] Experimental work dealing with the life history, habits, and control of the Mormon cricket was carried on by Mr. Boyd in that section until 1924. Little or no work was done in 1925, but in 1926 and 1927 the writer did similar work in Lake and Sanders Counties in western Montana. As a sequel to this experimental work a control campaign was instituted by the State of Montana in 1927, in cooperation with these counties. So highly successful was it that another campaign, based on its results, was carried on by the writer in the spring of 1928 in Routt and Moffat Counties, in northwestern Colorado. Here the Mormon cricket had been harmful since 1920, and had already directly or indirectly caused at least half of the homesteaders to desert their homes; and it was feared that if its ravages were not checked the country would be practically depopulated.

[1] *Anabrus simplex* Hald. Order Orthoptera, family Tettigoniidae, subfamily Decticinae.
[2] Resigned June 30, 1928.
[3] Of the Bureau of Entomology, United States Department of Agriculture, formerly located at the field laboratory at Billings, Mont.

Demonstration work was carried on in cooperation with the office of the State entomologist of Colorado, and with Routt and Moffat Counties, during the spring and summer of 1928, but owing to a shortage of available funds the work was limited. At the present writing (spring of 1929), preparations are under way to apply the results of this work in a comprehensive dusting campaign for the control of this pest in Routt and Moffat Counties, Colo., with Craig as the center of operations. Because most of the infestation is known to originate on lands held under public domain, the Federal Government is purchasing the poison and machinery required in applying it, and the ranchers have agreed to supply the necessary labor. The State of Colorado will furnish expert supervision for the project.

HISTORICAL

The first recorded occurrence of the Mormon cricket as an agricultural pest dates from 1848 in the Great Salt Lake Basin in Utah, and is best described by the following quotation from Bancroft (*1, p. 279–281*)[4]:

> The Spring [1848] saw everybody busy, and soon there were many flourishing gardens, containing a good variety of vegetables. In the early part of March ploughing commenced. The spring was mild and rain plentiful, and all expected an abundant harvest. But in the latter part of May, when the fields had put on their brightest green, there appeared a visitation in the form of vast swarms of crickets, black and baleful as the locust of the Dead Sea. In their track they left behind them not a blade or leaf, the appearance of the country which they traversed in countless and desolating myriads being that of a land scorched by fire. They came in a solid phalanx from the direction of Arsenal Hill, darkening the earth in their passage. Men, women, and children turned out en masse to combat this pest, driving them into ditches or on to piles of reeds, which they would set on fire, striving in every way, until strength was exhausted, to beat back the devouring host. But in vain they toiled, in vain they prayed; the work of destruction ceased not, and the havoc threatened to be as complete as that which overtook the land of Egypt in the last days of Israel's bondage. "Think of their condition," says Mr. Cannon—"the food they brought with them almost exhausted, their grain and other seeds all planted, they themselves 1,200 miles from a settlement or place where they could get food on the east, and 800 miles from California, and the crickets eating up every green thing, and every day destroying their sole means of subsistence for the months and winter ahead."
>
> I said in vain they prayed. Not so. For when everything was most disheartening and all effort spent, behold, from over the lake appeared myriads of snow-white gulls, their origin and their purpose alike unknown to the newcomers! Was this another scourge God was sending them for their sins? Wait and see. Settling upon all the fields and every part of them, they pounced upon the crickets, seizing and swallowing them. They gorged themselves. Even after their stomachs were filled they still devoured them. On Sunday the people, full of thankfulness, left the fields to the birds, and on the morrow found on the edges of the ditches great piles of dead crickets that had been swallowed and thrown up by the greedy gulls. Verily, the Lord had not forgotten to be gracious!
>
> To escape the birds, the crickets would rush into the lake or river, and thus millions were destroyed. Toward evening the gulls took flight and disappeared beyond the lake, but each day returned at sunrise, until the scourge was past. Later grasshoppers seem to have taken the place of crickets. They were of a kind popularly called iron-clad, and did much mischief.

In commemoration of this great service a very imposing monument was erected in honor of the gulls just within the gates to the temple grounds in Salt Lake City, Utah. Since 1848 the Mormon

[4] Reference is made by italic numbers in parentheses to "Literature cited," p. 28.

cricket has periodically caused more or less trouble to farmers in most of the States in the Rocky Mountain region. A glance at the accompanying map (fig. 1) will give an idea of the location of the outbreaks of this insect. The shaded portion denotes approximately its chief distribution, and the black spots the localities where outbreaks of it are known to have occurred and where they seem likely to occur again.

The name "Mormon" was probably adopted because of the incident just mentioned, and "cricket" because the insect somewhat resembles

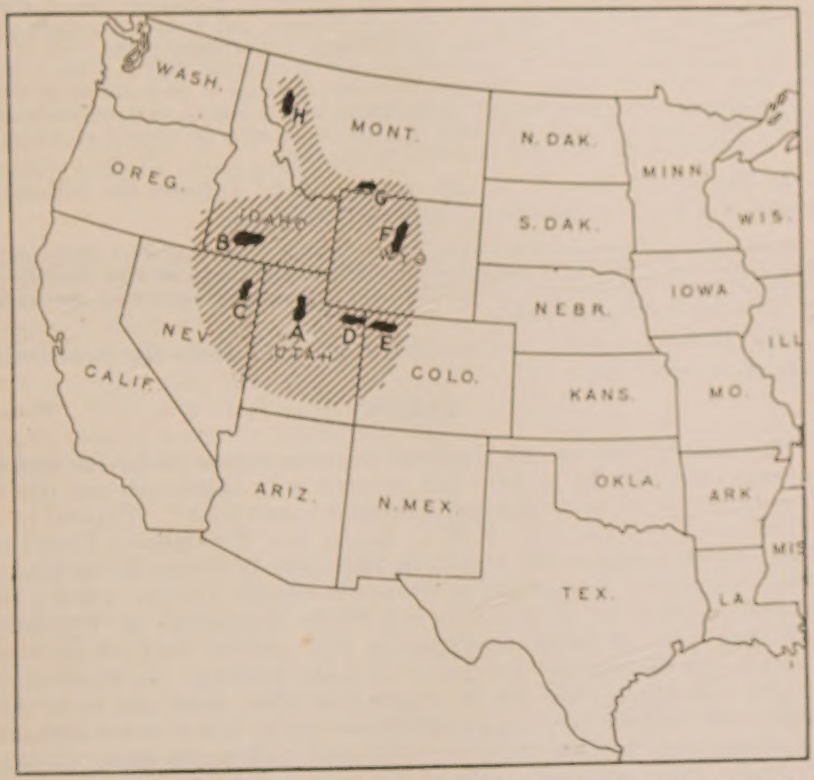


FIGURE 1.—Map of the western part of the United States, showing approximately by the shaded portion the chief distribution of the Mormon cricket. The black spots indicate the localities where outbreaks of the insects are known to have occurred, in the years named in connection with the reference letters: A, 1847–48; B, 1872, 1883, 1894, and 1904; C 1904; D, 1923–1926; E, 1879, 1895, 1900, 1902, 1905, and 1922–1928; F, 1923–1925; G, 1923; H, 1924–1928

the common black field cricket, especially its chirping noises. Technically speaking, however, this insect is not a cricket, but a wingless, long-horned grasshopper.

GEOGRAPHICAL DISTRIBUTION

The Mormon cricket is essentially an insect of the mountains, although it is known to be present in many of the States occupying the Great Plains. Thomas (*7, p. 431*), in 1872, referring to *Anabrus*

purpurascens, now considered a variety of *A. simplex*, made this statement:

> *Anabrus purpurascens* is found, not abundantly, but at certain elevated points from Northern New Mexico to Montana, along the east base of the mountains, but I have met with no specimen west of the range in the middle district, though Mr. Uhler gives Washington Territory as a locality, on the authority of Dr. Suckley. It is also found as far south as Texas, and as far north as Red River, in Northern Minnesota. *A. simplex* appears to be confined to the middle district, as I have not met with it east of the range, and have seen no notice of it being found either in the eastern or western districts. Dr. Scudder, who examined the *orthoptera* collected by Professor Hayden, in Nebraska, does not mention it in his list; nor did Mr. C. R. Dodge have it among his collections made in Nebraska, Colorado, Kansas, and Indian Territory; nor is it among the collections in the Agricultural Department made east of the Rocky Mountains. Hence I think we may safely conclude that it is confined to the west side of the range. But what it lacks in range is made up in numbers, for in the northern part of Salt Lake Basin and southern part of Idaho, the only points where I have met with it, it is to be seen in armies of myriads. But a fuller account of it will be found in the list.

In the same article (*7, p. 438*), in the "list," appears the following under the heading *Anabrus simplex* Hald.:

> Found in great abundance between Brigham City, Utah, and Fort Hall, Idaho. Also occasionally met with farther south in Utah and north of Fort Hall to the boundary line of Montana, which is here along the range separating the waters of the Atlantic from the Pacific.

The Mormon cricket has also been reported from the prairies of Manitoba by Criddle (*6*).

HABITAT

The natural habitat of *Anabrus simplex* seems to be in broken mountainous country more or less covered with sagebrush and native grasses, a type of country usually termed "scab land." Typical of it is that territory lying in Moffat, Routt, and Rio Blanco Counties, Colo., which embraces the Danforth Hills and Williams River Mountains. Southern Idaho and portions of eastern Oregon typify the natural habitat, as do also the Big Horn Mountains in Wyoming and that part of Montana lying in the eastern half of Sanders County and the northwestern part of Lake County. In these high, rugged hills the cricket can be found year after year, and it is only occasionally that it becomes plentiful enough to leave its natural surroundings and migrate into the cultivated valleys, to cause damage to crops. Such outbreaks usually last from two to six years, or until they are overcome by man, natural enemies, or weather conditions.

ECONOMIC IMPORTANCE

These periodical outbreaks have been occurring in certain localities in the West ever since farming secured a foothold there. The actual money value of crops destroyed by the Mormon cricket is difficult to estimate, because most of the records of its outbreaks are rather indefinite on this point. There is, however, enough information available to show that it is a pest of economic importance so far as the Rocky Mountain region is concerned.

In Moffat County, Colo., the cricket has been at least partially, if not wholly, the cause of a reduction in the number of farms under

cultivation in the infested territory from 429 in 1920 to 258 in 1927. The damage caused by the insect in 1922 in that county was estimated at $15,000 to $20,000 (*3*). In 1927 all crops in the newly infested territory in Routt County were damaged from 10 to 75 per cent. The loss in native grasses to the cattlemen in these counties is an item of considerable importance each year, although it is not possible even to estimate it.

It was estimated that in 1926 alone the farmers in Lake and Sanders Counties, Mont., lost more than 100,000 bushels of wheat because of the cricket. This loss, coupled with that of alfalfa, small fruits, and gardens, brought the total valuation of crops lost from this cause to approximately $125,000. In 1925 the loss was not so great, but probably amounted to several thousand dollars. These instances are the only ones in which estimates of damage to crops have been attempted, but undoubtedly outbreaks have occurred in other localities, in which the resulting damage was as great as or greater than in those here mentioned.

EXTENT OF INFESTATIONS

Crickets usually occur in bands varying in extent from the area of a city block to that of a square mile or even more. In the early stages of their development there may be as many as from 100 to 500 crickets per square foot. As they develop in size they spread over a larger area, but still remain pretty much in their respective bands. It is usually possible to find the outer limits of these bands, but in case of a severe infestation they may be so close together as to merge into one enormous horde covering thousands of acres.

NATURE OF INJURY

Damage to cereal crops often occurs in the spring, but as a rule it is not very important. The real injury is caused by the adult crickets after the grain is headed, while it is in the milk and dough stage (fig. 2), and even after it is cut and shocked. At these times only the heads are attacked and stripped of their kernels. During outbreaks of the grasshopper the heads of the cereal are as a rule left intact and will yield some grain, but in case of attack by crickets a badly damaged field yields practically nothing, not even enough to pay for harvesting. Figure 3 represents a field of winter wheat in western Montana completely ruined by Mormon crickets and Figure 4 a near view of standing plants in that field the heads of which have been stripped of their kernels by the crickets.

Alfalfa may be damaged at any time in the season, although the first crop ordinarily is damaged more seriously than either of the succeeding ones, owing to the fact that the grain is heading at about the time the first crop of alfalfa is being cut, and the crickets then ordinarily leave the alfalfa to enter the grain crops.

Garden crops are considered a delicacy by the Mormon cricket and are often eaten to the ground by it as fast as they make their appearance. Small fruits of all kinds are readily eaten and the bushes are stripped of their fruit as soon as it is formed.

SEASONAL HISTORY

Ordinarily the Mormon cricket completes its series of instars and reaches the adult stage between June 15 and July 15, and at the age of 10 days or 2 weeks the female cricket begins to lay eggs. Egg laying continues through July and August, and often into September. By the time frost occurs in the fall the eggs contain fully developed embryos, and are ready to hatch with the first warm days of spring. The exact date of hatching is very uncertain. In 1926, in Montana, a few crickets were hatched by the end of February, and the hatching was completed by March 20. In the same State, in 1927, the hatching occurred somewhat later and was not completed until some time in April. In Colorado, in 1928, a few crickets were hatched by the end of March, whereas in 1929 none were hatched until about April 15.

FIGURE 2.—Wheat heads stripped of their kernels by the Mormon cricket

Usually the seven nymphal stages cover from 75 to 90 days, extending from the date of hatching, as just described, to the time the adult emerges from the seventh molt, which may occur from early in June to the middle of July or later.

FIGURE 3.—Field of winter wheat in western Montana completely ruined by the Mormon cricket. This field should have produced 20 bushels per acre

The adult female, as has been stated, begins at the age of 10 days or 2 weeks to lay eggs, perhaps at any time in July or a little earlier or later, and continues this work for probably a month or more. Fertilization precedes egg laying by a very

short interval. It seems impossible in the present state of our knowledge to estimate with any approach to definiteness the average or the maximum length of life of the adult Mormon cricket. Table 2, page 20, presents the egg-laying performance of 15 female crickets in captivity, from the beginning of egg laying, in the case of each one, to the time of death. The shortest interval between these limits was 8 days and the longest 36, the average being about 26. But the life period of such insects in captivity is not a safe basis for estimating the life period under natural conditions. The hardiness of the crickets and their habit of seeking shelter under which they can withstand long periods of cold and of inclement weather favor longevity, whereas their habit of cannibalism and the fact that there are large numbers of predatory enemies which feed upon them reduce the likelihood of longevity.

FIGURE 4.—Near view of standing wheat plants in field shown in Figure 3. The heads of wheat have suffered the characteristic injury caused by the Mormon cricket

EXPERIMENTS IN REARING

The insects used in the writer's experiments in rearing were hatched from eggs taken in the field during the fall. These eggs were brought into the laboratory, where they were kept in cold storage until needed. They were then placed in moist sand in suitable receptacles, and incubated at room temperatures ranging from 65° to 85° F. Hatching took place within four or five days, and the nymphs were placed singly in glass tubes 1¼ by 8 inches in size and kept at the room temperatures mentioned. One end of each tube was closed with scrim, and a cork having a hole bored through it, covered with fine copper screen, was inserted at the other. The nymphs were supplied each day with a diet of sprouted wheat, lettuce leaves, apples, or onions. An examination was made each day for molted skins, and the date of the molt was recorded on the outside of the tube. A male and a female of each instar were photographed, and drawings were made of the last abdominal segments of each.

Table 1, compiled from notes by F. W. Boyd, gives rearing records for 16 individual crickets held at room temperatures ranging from 70° to 80° F. In each instance seven instars were recorded, and in all more recent experiments in rearing carried on in this laboratory that number has remained unchanged. The total time required from hatching to maturity ranges from 40 to 58 days, with an average of 50 days for the 16 individuals. The time required in nature usually is somewhat longer, being about 75 to 90 days. This difference is probably brought about by the greater variation in temperatures in the field, the very low temperature usually experienced in the early spring months having a tendency to retard the development.

TABLE 1.—*Rearing records of 16 individual Mormon crickets kept at room temperatures ranging from 70° F. to 80° F.*

Cricket No.	Duration of each instar							Total period from hatching to adult stage
	First	Second	Third	Fourth	Fifth	Sixth	Seventh	
	Days	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
1	7	11	6	4	9	5	9	51
2	8	14	6	8	4	6	11	57
3	9	9	4	4	9	5	9	49
4	9	11	5	7	6	5	11	54
5	9	10	4	4	8	5	8	48
6	8	12	5	10	3	7	7	52
7	11	5	4	6	6	5	13	50
8	10	7	5	5	5	6	12	50
9	11	4	4	8	5	6	14	52
10	12	5	7	7	7	7	13	58
11	8	7	4	7	5	4	8	43
12	12	4	5	7	4	5	15	52
13	10	5	6	6	5	6	7	45
14	11	5	6	6	4	6	11	49
15	7	5	6	8	4	5	5	40
16	10	4	4	7	5	6	14	50
Average	9.5	7.4	5.1	6.5	5.6	5.6	10.4	50.0

DESCRIPTION OF STAGES

EGG

The egg of the Mormon cricket is 7 to 8 millimeters in length, 2 to 2.5 millimeters in diameter, and tapered slightly at each end, and is protected by a thick, leathery chorion. It is laid in almost any type of soil, and under almost any condition of soil covering. When first laid, it is dark brown, changing almost immediately to a milky white on exposure to the soil. After remaining in the soil for some time, the egg gradually acquires a grayish color, which it maintains throughout the stage. As the egg is incubated in the soil the anterior end becomes swollen, owing to the growth of the head and thoracic regions of the young cricket, until, at the time of hatching, it is quite noticeably larger.

The length and breadth of 100 eggs were measured during the winter by F. W. Boyd. As the embryos were almost fully developed at this time the eggs were larger than when first deposited. The lengths ranged from 7 to 8 millimeters, with an average of 7.47; the widths averaged 2.12 millimeters, ranging from 2 to 2.5. Figure 5 represents a pile of 870 eggs collected from 1 square foot of soil.

The eggs are deposited in the soil at a depth of from one-fourth to 1 inch, and are laid singly, but often several eggs are laid by the same female in close proximity to one another. There seems to be no especial arrangement of the eggs in the soil, since they have been observed lying at practically all angles to one another.

FIGURE 5.—Eggs of the Mormon cricket, numbering 870, taken from 1 square foot of soil

FIRST INSTAR

When an egg is ready to hatch, the chorion splits lengthwise over the anterior end to about half way down the side. The young cricket, protected by the vitelline membrane, wriggles upward through the soil to the surface, where this protective sheath is discarded. On emergence the cricket is about one-fourth inch in length. It is then light tan in color, as it is immediately after each molt, but on exposure to the air it turns black in about an hour. The only markings are a wide band of white on the lateral posterior edges of the prothorax and a light stripe down the back, extending from the head to the tip of the abdomen. On emergence the body at first is quite

FIGURE 6.—First instar of the Mormon cricket: A, Female; B, male. Enlarged about 5 diameters

stout and robust, but as the cricket feeds it becomes more elongate. In Figure 6 is represented the female, A, and the male, B, of the first instar, each enlarged about 5 diameters.

Without the aid of a microscope it is impossible to distinguish between the sexes at this stage. However, a close examination of the ventral portions of the last abdominal segments shows plainly the six valves of the ovipositor of the female (fig. 7, A) and the subgenital plate of the male. (Fig. 7, B.) In this stage the rudimentary claspers of both sexes are of about the same size and show no distinguishable difference.

SECOND INSTAR

When the cricket is about a week or 10 days old the first molt takes place, and the insect emerges having the characteristic tan color, which soon changes to black, after which there are no distinguishable changes as to color and markings. Figure 8 represents the female (A) and the male (B) of the second instar, each enlarged about 3 diameters. A closer examination of the apical abdominal segments shows that the inside pair of valves of the ovipositor of the female have become distinctly divided and have increased in length. The inside pair are as yet plainly visible. (Fig. 9, A.) Little change can be observed in the male, except a slight growth in the subgenital plate and a subsequent narrowing of the angle between the two lobes. (Fig. 9, B.)

FIGURE 7.—First instar of the Mormon cricket: A, Ventral view of ovipositor of female; B, ventral view of subgenital plate of male. Enlarged 16 diameters

THIRD INSTAR

The second molt is an exact repetition of the first, there being no appreciable change in color or markings. (Fig. 10, A, B.) In the

FIGURE 8.—Second instar of the Mormon cricket; A, Female; B, male. Enlarged about 3 diameters

third instar, however, the ovipositor is plainly visible to the naked eye, although it does not as yet extend to the tip of the abdomen. Examination of the ovipositor with a binocular microscope shows that the inner pair of valves are completely incased in the two outer pairs. (Fig. 11, A.) No difference can be seen in the claspers of the two sexes. (Fig. 11, A, B.) The two lobes of the subgenital plate of the male have increased in length, with a further narrowing of the angle at the base and a lessening of the distance between the lobes. (Fig. 11, C.)

FOURTH INSTAR

In the first three instars the insects all become uniformly black shortly after hatching and after each molt, but in the fourth instar (Fig. 12) a variation in color is sometimes observed, the colors rang-

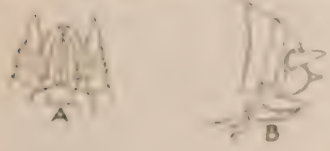
ing from green to brown or black. The ovipositor of the female has become twice as long as that borne in the previous instar, and extends well past the tip of the abdomen. (Figs. 12, A, and 13, A.) In this instar is to be seen the first indication of a difference in the claspers of the two sexes—those of the male begin to flatten on the inside and to curve inward. (Fig. 13, C.) The first signs of bifurcation are also noticed in the male cerci, while those of the female remain round and straight, and never increase greatly in size with further growth.

FIFTH INSTAR

In the fifth instar (fig. 14) the insect is somewhat increased in size, and the variation in color is even more marked than in the pre-

FIGURE 10.—Third instar of the Mormon cricket. A, Female; B, male. Enlarged about 3 diameters

ceding instar. The ovipositor of the female has again doubled in size, being now about one-third of the length of the hind femur. (Figs. 14, A, and 15, A, B.) The cerci of the male are much more developed, being now quite noticeably branched and curved. (Fig. 15, C, D.)



SIXTH INSTAR

In the sixth instar (fig. 16) the ovipositor of the female is again doubled in length, being now three-fifths of the length of the hind femur. (Figs. 16, A, and 17, A, B.) The upper hook of the clasper of the male is now quite prominent, but remains blunt and rounded, while the lower one is decidedly hooked and pointed. (Figs. 16, B, 17, C, D.)

SEVENTH INSTAR

In the seventh instar (fig. 18) the ovipositor of the female is once more doubled in length, it being now a little longer than the hind

femur. (Fig. 19, A, C.) The claspers of the male are about fully developed, both lobes being pointed and hooked. In the case of both sexes this instar closely resembles the adult in size and shape, but

FIGURE 12.—Fourth instar of the Mormon cricket. A, female; B, male. Enlarged 3 diameters.

closer examination of the rudimentary wings shows them to be not so fully developed as they are in the adult.

ADULT

The ovipositor of the adult female, although not relatively longer than in the seventh instar, is much heavier and thicker at the base. (Figs. 20, A, and 21, A.) The wings of both sexes have reached their highest development, those of the female meeting at the middle of the back, but not showing from under the prothoracic shield. (Fig. 20, A.) The wings of the male are much longer, showing plainly from underneath the prothoracic shield and overlapping somewhat to form a stridulating organ. (Fig. 20, B.) The ovipositor of the female and the claspers of the male are shown in Figure 21.

FIGURE 13.—Fourth instar of the Mormon cricket: A, Ventral view of prothorax of female; B, side view of same; C, ventral view of hypogynial plate of male. Enlarged about 5 diameters.

MOLTING

The molting of the young crickets is a very interesting process to watch and usually takes from 15 to 20 minutes. When an individual is ready to molt, it climbs up on a stem of grass or any other convenient object and fastens itself securely by its hind feet, with the head pointing downward. As soon as the feet are securely fastened convulsive muscular contractions begin to take place within the body, forcing it upward so that pressure is brought to bear on the dorsal

surface of the integument. Soon the integument begins to split along the dorso-median line, commencing above the eyes and extend-

FIGURE 14.—Fifth instar of the Mormon cricket. A, Female; B, male. Enlarged 4 diameters.

ing backward to about midway of the abdomen. The ventral prothoracic is forced open by further muscular contractions, and the upper part of the thorax is visible. The body is then slowly withdrawn from the old skin by a series of twisting movements of the body from side to side, commencing with the head and continuing with the mandibles, the antennæ, and the two anterior pairs of legs. The hind femora are then withdrawn, with the aid of the front legs and with further twistings of the body, and finally the tip of the abdomen emerges. On freeing itself from the cast-off skin the insect sometimes drops to the ground, where it remains inactive until the new cover-

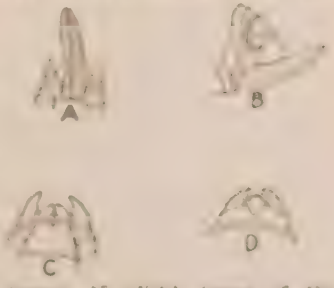


FIGURE 15.—Fifth instar of the Mormon cricket. A, Ventral view of prothorax of female; B, lateral view of same; C, ventral view of prothorax of male; D, dorsal view of same. Enlarged 4 diameters.

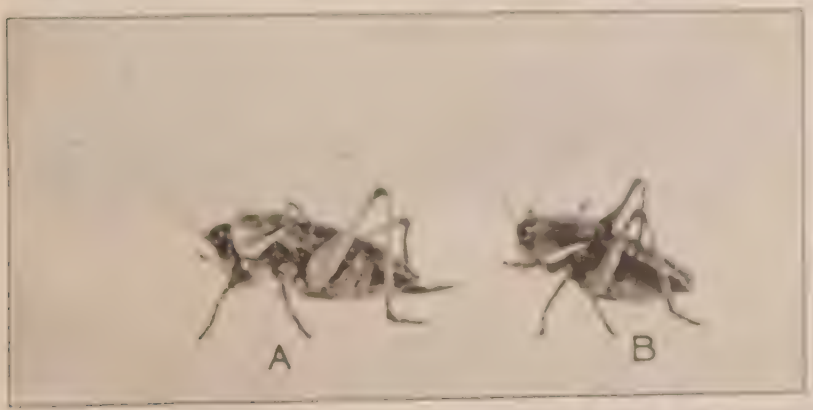


FIGURE 16.—Sixth instar of the Mormon cricket: A, Female; B, male. About natural size.

ing has hardened and turned black. In case it does not drop to the ground it frequently turns and eats the cast-off skin left hanging to

the supporting stem. In rearing tubes the cast-off skin is almost always eaten.

REACTIONS

The Mormon crickets are, as a rule, inclined to be timid. On approaching a "bunch" of them gathered together on a bare spot surrounded by heavy vegetation one has to be cautious in order to get very close. As soon as the presence of an intruder is noticed they all immediately scamper for shelter and soon lose themselves in the vegetation. It is interesting to observe the effect of a sudden motion on a migrating band. Those nearest the source jump away from it, thus exciting others near by, and the motion spreads out in waves resembling those produced by casting a stone into a quiet pool of water. These waves gradually subside as the distance from the source is increased, until they die out entirely. When, for any reason, one cricket is disturbed it immediately jumps as far as possible in a lateral direction away from the cause of the excitement. This sudden movement is taken up by other crickets until, beginning at the source, a wave of jumping crickets is spread out in a fan shape and advances for some distance, until it finally dies out.

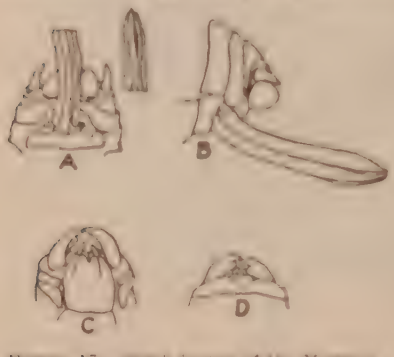


FIGURE 17.—Sixth instar of the Mormon cricket: A, Lateral view of head and prothorax of female; B, lateral view of female; C, ventral view of male genital plate of male; D, dorsal view of male. Enlarged 4 diameters

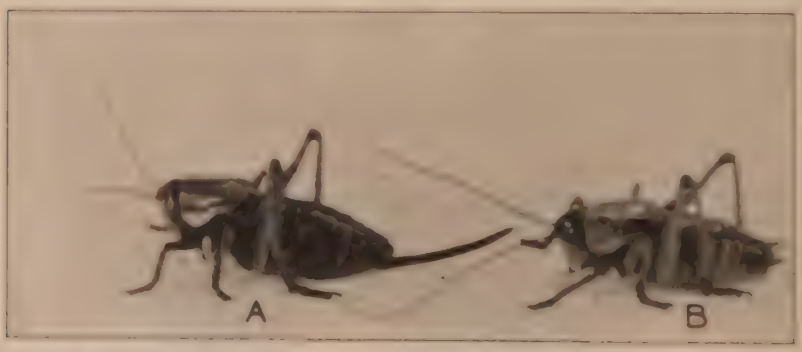
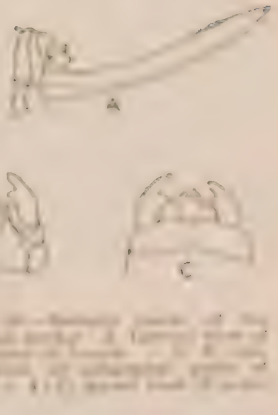


FIGURE 18.—Seventh instar of the Mormon cricket: A, Female; B, male. About natural size

Owing to the fact that Mormon crickets hatch at a much lower temperature than do grasshoppers, they usually make their appearance about a month earlier. In the first and second instars it is necessary for them to pass through the cold spells that usually occur in the early months of spring. Undoubtedly some die during this cold weather, but for the most part they survive, mainly because of

their habit of congregating under dry grass manure, rocks, or whatever rubbish is available, until the cold spell has passed.

During the warmer weather the young crickets spend their days in the open, and at night seek cover in much the same way. About sundown the crickets gather in piles an inch or two deep and a foot or more across; somewhat later these clusters are broken up and the insects disappear under cover for the night. Early in the morning (provided it is daylight), when the temperature reaches about 40° F., they begin emerging from their night shelters and gather in small clusters until the sun is well above the horizon, when these clusters are again broken and the daily activities commence. It has been observed that a passing cloud, momentarily obscuring the sun, causes them immediately to form in clusters. A shower drives them to shelter, from which they emerge when it has passed, and again gather in clusters until they become warmed.



These habits of clustering on the warm, bare spots, and seeking shelter during the night and inclement weather, are adhered to throughout the life of the cricket. The adult is not so likely to are the nymphal instars to seek shelter at night, but this fact may be due

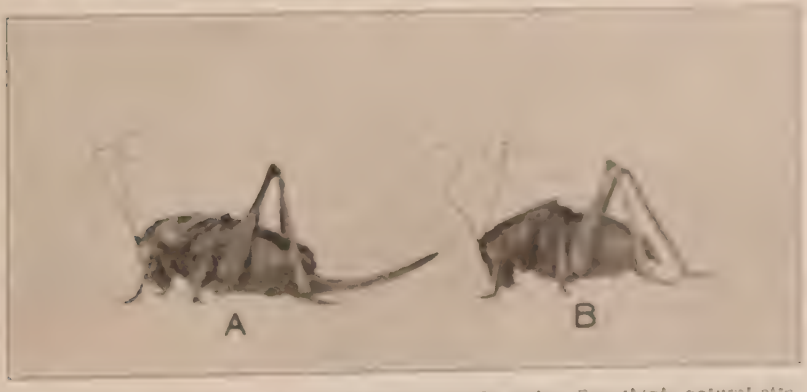


FIGURE 20.—Adult Mormon cricket. A, Female; B, male. Two-thirds natural size.

to the higher temperatures that prevail after the final stage has been reached. They do, however, cluster at sundown, especially on fence and telephone posts and the sides of buildings. These clusters are sometimes broken later, and the migrating or feeding resumed.

High temperatures at the surface of the ground during the day drive the adults up on weeds, fences, and buildings. This usually occurs when the surface of the soil reaches a temperature of 100° F., or thereabouts. When the temperature falls they descend to the ground and continue their activities.

FOOD PLANTS

Among the uncultivated plants, the following, in order, are the most desired for food by the crickets in Montana:

Common name	Scientific name
Bitterroot	*Lewisia rediviva* Pursh.
Tumbling mustard	*Sisymbrium altissimum* L.
Common mustard	*Brassica arvensis* (L.) Kuntze.
Hare's-ear mustard	*Conringia orientalis* (L.) Dumort.
Dandelion	*Taraxacum officinale* Weber.
Prickly lettuce	*Lactuca scariola* L.
Russian thistle	*Salsola pestifer* A. Nels.

The bitterroot, which is very common in western Montana, is a especially favored food plant of the young crickets, probably because its leaves are thick and juicy, and because it makes its appearance early in the spring. Practically all the mustards, especially tumbling, or "Jim Hill" mustard, are highly favored early in the spring, and throughout the entire growth of the crickets are eaten more readily than any other native plants. The seeds seem to be considered a great delicacy by the adults, and the pods of practically every mustard plant in cricket territory are found to be stripped of them. Dandelion is also eaten readily in the spring, but not to so great an extent later in the summer. Russian thistles are eaten only when very young and tender.

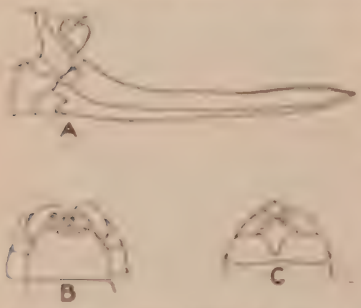


FIGURE 7.—Adult Mormon cricket: A, Lateral view of prothorax of female; B, ventral view of pronotum of male; C, dorsal view of same. Enlarged about 2 diameters.

To the foregoing list of uncultivated plants, Corkins (3) adds the following: Sagebrush, buck brush, scrub oak, willow tree, lupine, service berries, and miscellaneous wild legumes.

Practically all of these plants except scrub oak occur in Montana, but crickets have never been observed eating them, possibly because other vegetation more to their liking was present.

There seems to be no limit to the variety of cultivated crops that crickets feed upon and damage. Garden crops of all kinds, fruits, including gooseberries, currants, and apples, and practically all field crops, are readily eaten.

CANNIBALISM

Throughout the entire life of the Mormon cricket cannibalism is a marked habit. Both in the field and in the laboratory the crickets have many times been observed feeding on one another, regardless of the abundance or scarcity of food. Scarcity of food may be an impetus to cannibalism but is not a necessary cause. In this habit there seems to be no discrimination between the sexes, since males have been observed feeding on females, and vice versa. Undoubtedly the females are more susceptible to attack than males, especially during the egg laying period, since they may then become weakened and more easily fall a prey to their fellows. While laying eggs they

must become fixed for a time in one spot, thus making themselves more liable to attack. Few crickets that are able to get out of the way are killed and eaten, but as soon as one becomes handicapped by the loss of a leg or by other injury it is immediately pounced upon and devoured. Great numbers are crushed when crossing highways where vehicles are passing. Their more fortunate fellows immediately gather to the feast, until the passage of a car or wagon through a band can be traced by the two black lines of crickets gathered to eat those that have been injured. Tales of crickets being so numerous on the roads as to force motorists to put chains on their cars in order to get through them may be highly exaggerated, but one can see how this might happen. The insects may keep accumulating in the wheel tracks, to be run over by oncoming cars and their crushed bodies form a slippery mass not unlike soft mud. Vague stories have been heard from time to time concerning this experience but have never been substantiated.

MIGRATIONS

The habit of migration has caused more conjecture and comment than any other habit of the Mormon cricket. For the last 25 years observers have been trying to determine why the insect migrates and what it is that influences the direction of migration. The opinion has been advanced by some that the crickets travel toward the sun; others have opined that they travel with the wind, and still others believe that they travel against the wind; however, of all the many theories that have been advanced not one holds true. Bands of crickets have been observed traveling toward the sun and, a half mile farther on, another band traveling exactly in the opposite direction or at right angles to it. In fact, it is entirely possible to find a series of bands of crickets "boxing the compass," traveling up hill and down, toward and away from cultivated crops, all in a single day and within the radius of a few miles. There seems to be no means of telling whether the crickets will travel east, west, north, or south. The fact remains that they do travel en masse, usually in a straight line, and stop for nothing. What urges them to travel in a given direction and the reason why they travel at all are matters of sheer conjecture.

It has been possible to trace during a period of years infestations in a given direction for a given locality. In northwestern Colorado the infestation for the period from 1921 to 1927 has moved distinctly eastward. In western Montana the general direction of the migration during a period of three to five years has been toward the south. In Washakie and Big Horn Counties, Wyo., the general direction of migration has been toward the north. The reason why these directions were chosen is so far only a matter of guesswork, and probably years of intensive research would be needed before any definite conclusions could be reached, if an explanation could be found even then.

From the time the crickets hatch in the spring until they disappear in the fall they are almost constantly on the move, if weather conditions are favorable. They do not as a rule travel very far while in

the first four instars, but move about apparently in search of food. The big migrations take place in the interval from the time they reach the fourth instar until their activities are over in the fall. During these migrations the rate of progress ranges from one-eighth of a mile to 1½ miles a day. Corkins (12) records one instance in which a band traveled 1½ miles in one day. Johnson (21) records one in which it took a band of crickets one week to cover 5 miles, or about three-fourths of a mile a day. The distance traveled varies somewhat with the different stages, the crickets in the instances mentioned having been adults. Weather has a marked influence on the migrations, little or no travel taking place during wet, gloomy weather. They cease entirely when the temperature at the surface of the soil reaches approximately 103° F. Most of the moving is done by daylight, although the crickets have been observed traveling at night.

When a band begins moving it travels in a straight line and stops at nothing. If a board fence, a house, or other obstacle is encountered the crickets will try to climb over the top instead of going around. An instance is called to mind in which a band of these insects entered an open-air pavilion in a town in Wyoming where a dance was in progress. Their crushed bodies soon made the floor so slippery and nauseating that all the dancers had to stop and leave the place.

REPRODUCTION

Courting and mating usually take place from 10 days to 2 weeks after the crickets reach the adult stage, and occur in the forenoon between the hours of 8 and 12. The following description of the process written by Yothers (35) for *Peranabrus scabricollis* describes it very well for *Anabrus simplex*, and little can be added:

> If a male is confined with a female he courts her somewhat after the fascinating manner. At about eight or ten o'clock, if the morning is fairly warm and bright, he begins to chirrup to the female, who does not seem to pay any attention to his advances, but as he continues to sing and ride up to her feeling antennæ with her and trying to get between her, she gradually becomes less indifferent to his pleading, but shows almost no response to all his blandishings. She does not attempt to escape from him, but by gently but firmly pushing him away with her nearest feet, when he makes too ardent advances, she shows that she is not to be too easily won. After she assumes a decidedly receptive attitude and the male attempts to mount, but after many trials—the remaining patient) still the male—he gives up and goes away. One pair was observed courting and attempting copulation for two and one-half hours before they finally separated without mating. In another case the pair had courted only a few minutes when the female advanced toward the male, walked over to him then stopped and waited while he caught hold of her with his hooked cerci. After a few seconds there were several shivering pulsations of the male's abdomen, and the white spermal sac appeared and was passed to the female. The female pulled away at once then, turned the male over and tore the mass from him. The actual process of copulation lasts from three to ten minutes, after which the female goes about with her ovipositor well up off the ground so that the sticky mass will not become covered with particles of dirt and other rubbish. After a few minutes she may laugh beneath herself and eat away a portion of the spermal sac; or her male consort or her other comrades may eat away some of it; but the greater part and perhaps, under normal conditions, all of it, is inserted into the bursa copulatrix. After an hour or so the mass has entirely disappeared.

Oviposition may take place at any time of the day, although the greater number of eggs are probably laid in the afternoon. When a female is ready to deposit eggs she walks around over the surface of the ground with the tip of the abdomen raised so that the ovipositor is in a vertical position. In this manner the soil is tested in several places until a satisfactory spot is found. The ovipositor is then worked into the soil by a shuttle-like movement of the right and left pairs of valves, brought about by muscular contractions of the abdomen, until it is inserted to the farthest depth obtainable. The egg is then passed down between the two outer pairs of valves, aided by the inner pair. As soon as the egg is placed in the soil the ovipositor is withdrawn and the entrance to the hole is covered with dirt by a few quick, backward movements of the ovipositor. The insect then moves on to another location, where the process is repeated.

There seems to be very little choice in the selection of a place for egg laying. Practically all types of soil are used, ranging from a hard packed road to summer fallowed wheatland, but apparently a firm, sandy soil is favored. A sunny location is usually chosen, with an eastern, western, or southern exposure. The northern exposures are for the most part ignored. Bare ground is usually preferred, but eggs have been collected in native grassland and in alfalfa fields, tucked in around the bases of the plants and even in the crowns of the clumps.

The number of eggs laid by a single female in the field is undoubtedly quite variable. Of 15 females individually caged with mates at the field laboratory at Billings one laid as many as 193 eggs, and the average for the 15 was 85.5, the total for all being 1,282. As many as 35 eggs were laid by a single female in one day. The results of these experiments are summarized in Table 2. It was found that a female was able to lay eggs about once in every seven or eight days, from the time the first eggs were deposited until she died. Since several of the females used in the laboratory experiments died after laying only a few eggs, it seems probable that natural field conditions would aid the egg laying and bring the general average for the number of eggs for an individual nearer to 150 or 160.

TABLE 2.—*Record of eggs laid by 17 Vermont ringlets, kept individually caged with pairs of the same sex, at the end of [illegible] at Ithaca, N. Y., on the natural day of [illegible]*

Number of eggs laid on consecutive days numbered—

Dead

Table 2 presents the record of each of the 15 females [illegible] each consecutive day from and including the day of her first oviposition to and including the day of her death, the actual dates not being given. For instance, under "2" in the last heads is shown the record of each cricket for the day after that of her first oviposition. The dates of first oviposition ranged from June 29 to July 5.

NATURAL CONTROL.

PREDATORY ENEMIES.

The Mormon cricket, being large and clumsy and not capable of flight, easily falls a prey to many predatory enemies. Of these the birds are the most important. Every band of crickets is marked by a following of crows, blackbirds, or robins; crows seem especially fond of this insect and gather in groups of from 10 to 30 to feast upon it. The following list of birds will give an idea of the great variety of enemies of this insect:

Common name	Scientific name
California gull	*Larus californicus.*
Franklin's gull	*Larus pipixcan.*
American bittern	*Botaurus lentiginosus.*
Richardson's grouse	*Dendragapus obscurus richardsoni.*
White-tailed ptarmigan	*Lagopus leucurus.*
Sharp-tailed grouse	*Pedioecetes phasianellus columbianus.*
Sage grouse	*Centrocercus urophasianus.*
Swainson's hawk	*Buteo swainsoni.*
American sparrow hawk	*Cerchneis sparverius.*
Horned lark	*Otocoris alpestris* subsp.
American magpie	*Pica pica hudsonia.*
Mexican raven	*Corvus cornix sinuatus.*
Common crow	*Corvus brachyrhynchos brachyrhynchos.*
Western crow	*Corvus brachyrhynchos hesperis.*
Piñyon jay	*Cyanocephalus cyanocephalus.*
Western meadowlark	*Sturnella neglecta.*
Brewer's blackbird	*Euphagus cyanocephalus.*
Lark bunting	*Calamospiza melanocorys.*
Western robin	*Turdus migratorius propinquus.*

To this list of wild birds may be added all kinds of domestic fowls, chickens and turkeys being the most important.

The cricket has proved to be a very good food for chickens and turkeys. The bodies of crickets, although composed largely of water, are rich in protein. Large bands of turkeys have subsisted almost entirely on crickets until fattening time in the fall and, among all of them, only one turkey was ever observed to have become "crop bound." The only other undesirable result of this diet was an occasional case of diarrhea. It may be remarked that a very high percentage of the turkeys from "cricket country" were graded No. 1 when placed on the market. A prime diet of crickets seems to be all right for growing chickens, but is not so desirable for laying hens. It has many times been observed that hen's eggs from territory infested with crickets have dark-colored yolks, and have come to be known to the produce buyers as "cricket eggs." This discoloration of the yolk of course makes the eggs very undesirable to the housewife, and consequently eggs from territory infested by crickets are for the most part avoided by the buyers.

Among the other predators, rodents, including several species of gophers, ground squirrels, and marmots, are fond of Mormon crickets. Coyotes, skunks, and badgers undoubtedly eat great numbers of this insect, but of course the actual value of any of these animals as a means of control is problematical.

On the authority of F. W. Boyd, who did extensive work with the cricket in Wyoming in 1922, 1923, and 1924, sheep might be added to this list of predators. In his field notes he has recorded several observations of sheep which have been seen eating them as a repast, with apparent enjoyment. No observations of this kind have been made, aside from those made by Mr. Boyd, as the cricket has required very little attention in Wyoming since 1924, and conditions favorable to such a phenomenon have not been found elsewhere.

INSECT PARASITES

Parasites of the Mormon cricket are very limited in number, perhaps largely because the crickets are extremely cannibalistic. It is

FIGURE 22.—*Sparasion pilosum*, an egg parasite of the Mormon cricket. A female has emerged from the pupa case on the right. The empty case is shown with the lid open. Enlarged about 4 diameters.

easy to see how a cricket infested with some internal parasite would, on becoming weakened, fall a prey to the more fortunate crickets and be devoured. Not only would the infested cricket be destroyed but the parasite as well. There are, however, one parasite and a predator known that may be considered as somewhat helpful in controlling this insect. *Sparasion pilosum* Ashm., a hymenopterous insect, is a parasite of the eggs of *Anabrus* (fig. 22), as has been recognized for some time by entomologists, but its actual value as a control has never been considered great. Observations in western Montana have shown, however, that it is a factor not to be overlooked. In 1926 a very high percentage of the eggs laid in the Charlo district in Lake County, one of the worst infested places in 1925 and 1926, were parasitized. In this district in 1927 very few crickets hatched, and little or no control work was necessary. Other districts in Lake County were not so fortunate, although parasitism ranged as high as 50 per cent in the vicinity of Round Butte, and

the control work was noticeably less in 1927. Eggs collected from all parts of the infested territory in the fall of that year show a very high percentage of parasitism.

This parasite lays its eggs inside the cricket egg, probably after the latter is deposited. Within a month or six weeks after the parasitized eggs have been laid they can be distinguished from those that contain cricket embryos. Parasitized eggs do not increase in size after they are deposited, whereas those not parasitized develop normally and noticeably increase in size. The parasite apparently develops only at a high temperature, and therefore undergoes little or no development in the fall. Practically all its development takes place in late spring and early summer, and it is ready to emerge about the time egg laying begins.

The other known insect enemy, the wasp *Tachysphex laticornis* Cress.,[2] is predatory and was observed for the first time attacking Anabrus in western Montana in the spring of 1926, by the writer, in charge of the control campaign. Through the summer great numbers of this insect could be observed busily digging their burrows and burying crickets. Their exact procedure, if any is followed, is not known. It has been observed, however, that the wasp stings its victim several times, if necessary, paralyzing the cricket and rendering it helpless, but does not cause its death. The cricket is then dragged into the wasp's burrow, which may or may not have been previously dug, and the egg of the wasp is attached to the membranous tissue in the cricket's side, near the hind leg. When the young wasp hatches it remains where the egg was attached and begins to feed. When it has attained its full growth pupation takes place without any change of position, as is evident from pupæ protruding from the soil still attached to the remaining pieces of the cricket, which served as its food. Although it is reported that as many as five pupa cases have been taken from one burrow, the usual number in a burrow is two.

Little can be said as to the value of this predatory wasp in controlling the Mormon cricket, inasmuch as 1927 was the first year in which it was observed in large numbers on this particular insect. Further work on its habits and life history is necessary before any definite statement on this point can be made, but it is highly probable that if this insect were plentiful enough it would be a decided factor in the control of the Mormon cricket.

ARTIFICIAL CONTROL.

BRAN MASH

Experiments have been carried on for years with bran mash in order that an effective method of controlling the Mormon cricket might be found. Although some good results have been obtained, more especially with crickets in the younger stages, it is believed that poisoned bran mash is not a reliable means of control. The insects are very erratic in their feeding, and whereas good results may be obtained one day, poor results may be found the next. Then, too, since the insects are almost constantly in motion, it is very diffi-

[2] Determined by Nathan Banks.

suit to see the actual results, and in the case of the average farmer "seeing is believing."

After much experimentation the following bran bait has given the best results, but even with this one the results have at times been very mediocre:

Bran	100 pounds.
Amyl acetate	3 ounces.
Salt	5 pounds.
Liquid sodium arsenite	8 pounds (3 to 4 quarts).
Water	11 gallons.

BARRIERS

Mechanical control by means of barriers is completely effective in stopping migrations of the Mormon cricket and in destroying the insects themselves. These barriers consist of objects over which the insects can not climb, and must have pits dug at intervals along their sides to trap the crickets encountering them. The main objections to these barriers are the cost, the difficulty with which they are handled, and the attention required for their operation. Several types of barriers have been tried out, and all have been fairly successful. A sheet-metal barrier now in use in Colorado is perhaps the best, but it is also the most expensive. It consists of a 10-inch strip of galvanized iron, and the material costs from 5 to 10 cents per foot, or approximately $265 to $530 per mile. The barrier used in Washington against the Coulee cricket is very good; it consists of an 8-inch board set on edge, with a 4-inch strip of tin nailed on the top, projecting outward at right angles from the board toward the direction from which the insects approach. Where such a barrier can be constructed to extend across a ditch full of water (fig. 24) it becomes very effective. This barrier should cost in the neighborhood of $250 per mile, the expense depending upon the cost of lumber in any particular region. It is very effective, but requires more attention than the sheet-metal barrier, and is harder to transport and set up.

The least expensive type of barrier is one devised by a farmer in western Montana. It consists of a board 8 inches wide set at an angle of 45° or 50° above the ground, and having a 3-inch strip of oilcloth fastened to the inner side near the top by means of a paste made of flour and water. (Fig. 23.) The cost of this barrier should not exceed $150 per mile. It is effective, but requires constant attention and, like the board-and-tin barrier, is hard to transport and to set up.

It is believed by many that all of the barriers that have been tried are too expensive to use in actual control work. They are, however, very useful in stopping migrating bands when the depth of the band is much greater than the width. A barrier was used quite effectively in Washington against the Coulee cricket (9), and this method of control has also been used in Colorado and Utah. Five miles of the all-metal barrier were constructed in Routt County, Colo., in the summer of 1927, and the device was instrumental in stopping migratory bands of the Mormon cricket before any very serious damage was done.

ARSENITES

Owing to the fact that poisoned bait has not under all conditions been found efficient in control of the Mormon cricket, and since

FIGURE 23.—A, A barrier made of an 8-inch board, to which is attached a strip of oilcloth 3 inches wide; B, a nearer view of the same barrier with crickets massed in front of it

barriers are expensive and hard to handle, a need for a better method of control has been felt. Experiments have accordingly been carried out with various dusting and spraying materials which appeared suitable for killing the insects by direct or indirect contact. Of all

the materials tested, powdered arsenites of sodium and calcium proved the most effective. Either of these materials, mixed with hydrated lime in the proper proportions and dusted over the swarms, is very effective against this insect in almost any stage of its development.

This method of control was used almost exclusively in the campaign in western Montana in 1927, both arsenites being employed, and was so effective that the loss to crops from the cricket was less than 10 per cent in an area that suffered loss of 100 per cent in 1926. The sodium arsenite was used in the proportion of 1 pound of arsenite to 4 pounds of hydrated lime, and was applied at the rate of 5 pounds of the dust per acre; the calcium arsenite was less diluted, there being 1 pound of the arsenite to 3 pounds of hydrated lime, and 8 pounds of the dust was used per acre. The powder was applied with dust guns, directly on the swarms of insects. Results could be seen in from 12 to 24 hours after the application and the mortality among the crickets at the end of a 4-day period ranged from 75 to 100 per cent. Although results from these insecticides were excellent in western Montana in 1927, it is believed that further experience with them is necessary, particularly in other localities, before any definite statements can be made regarding the use of arsenites for controlling the Mormon cricket.

FIGURE 24.—A very effective "water trap" used against the Mormon cricket in some irrigated districts

SUMMARY

The Mormon cricket is essentially an insect of the mountains, although it is known to be present in many of the States occupying the Great Plains, and its habitat extends across the United States, from Texas to Minnesota. It is not really a cricket, but is a wingless, long-horned grasshopper. It naturally inhabits high, rugged hills in mountainous country, from which it migrates from time to time into cultivated valleys, to cause damage to crops. From 1848 to the present time it has been known as a serious pest to agriculture, sometimes causing losses amounting to thousands of dollars, and seriously reducing the number of farms under cultivation.

The crickets usually occur in bands varying in extent from the area of a city block to a square mile or more. The bands are very dense, there being often from 100 to 500 to the square foot. In general, cereals are injured by them more than are other crops. Alfalfa, garden crops, and small fruits are severely attacked.

The Mormon cricket reaches the adult stage early in the summer, and its eggs are laid in the summer and early in the fall and hatch in the following spring.

Between the stages of the egg and the adult are 7 nymphal stages, in all lasting from 75 to 90 days. When hatched from the egg and after each molt the insect is light tan in color; on exposure to the air it soon turns black in the first three instars, but with some variation in color in the remaining four. Although the insect is wingless, rudimentary wings develop and become visible in the seventh instar and in the adult. The development of the posterior organs has been especially observed from instar to instar, in particular the cerci, the claspers, the subgenital plate of the male, and the ovipositor of the female, until it is completed at the time the adult emerges from the seventh molt.

The adult stage is attained in the early part of the summer, usually between the middle of June and the middle of July. At the age of 10 days or 2 weeks the female begins egg laying, which is continued to the end of summer or early in the fall. The duration of the life of the adult seems to be not well understood. The insect is hardy and frequently makes good use of shelter as a protection against cold and inclement weather, but reducing the likelihood of longevity are its pronounced cannibalistic habit and a great number of predatory enemies.

The food of the Mormon cricket includes a considerable number of uncultivated plants, bitterroot and several kinds of mustard being especially favored, and practically all kinds of field and garden crops. The fondness of this insect for nearly everything in the way of plant life grown by the farmer is the cause of its great economic importance as a pest.

From the time the crickets hatch in the spring until they disappear in the fall they are almost continually in motion when the weather is favorable. The migrations of their bands, apparently in search of food, depend somewhat upon the weather and vary greatly in speed. A band, once under way, travels in a straight line and stops at nothing. The cause of their choice of any particular direction has always remained a mystery.

Mating occurs 10 days to 2 weeks after the adult stage is reached, and oviposition follows shortly afterwards. Eggs are laid at any time in the day, probably more especially in the afternoon, and in any kind of soil. The number laid by one female varies greatly, but the rate of oviposition in the field is not well known.

Notwithstanding the hardiness and activity of the Mormon cricket, it is large and clumsy and incapable of flight, and suffers from the ravages of many predatory enemies, wild birds being the most important. Domestic fowls consume great numbers of the crickets and find them a very good food. Various rodents, such as gophers and ground squirrels, are fond of them. Besides these and other animals, sheep have been known to eat them freely.

Among insect enemies of the cricket are one hymenopterous insect, *Sparaison pilosum* Ashm., which parasitizes the eggs of the cricket, preventing their development, and a predatory wasp, *Palm-*

odes laeviventris, which stings crickets, paralyzing them, and drags them to its burrow, where they later serve as food for the young of the wasp. The economic value of these insects in controlling the cricket is as yet not well determined.

Artificial control by means of poisoned bait has not been found reliable, although some good results have been obtained with a poisoned bran mash. Encouraging results have been obtained from experiments with powdered arsenites of sodium and calcium, mixed in proper proportions with hydrated lime and dusted over the swarms. Mechanical control by artificial barriers is completely effective in stopping migrations of the cricket and in destroying the insects themselves, but they are expensive and difficult to handle. Several types of barrier have been tried and found successful. They were constructed of various materials, such as metal, metal and wood, and wood and oilcloth.

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U. S. GOVERNMENT PRINTING OFFICE: 1929

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